NASA TECHNICAL MEMORANDUM

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NATIONAL ALTITUDE ROCKET TEST FACILITIES

by Jack A. Suddreth

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Office of Advanced Research and Technology
Washington, D.C.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

The necessity for experimental verification of rocket-engine performance at altitude or near-space conditions has long been recognized in the aerospace industry. Recent spacecraft rocket-engine research and development trends toward higher area ratios, advanced nozzle concepts, and nonequilibrium flow considerations have made altitude simulation a requirement of development programs. Because the need for information regarding the capabilities and characteristics of altitude test facilities that are suitable for liquid-rocket-engine operation was recognized, this survey was compiled with the help of representatives of industry and government agencies.

INTRODUCTION

The advent of upper-stage and spacecraft engine-vehicle development programs along with the need for more rigorous performance and reliability data justified the construction of a number of altitude test facilities. The test capabilities of these facilities range from small attitude-control engines to large upper-stage engines. The altitude-simulating systems include simple diffusers coupled to the engine nozzle exit (fig. 1), steam ejector coupled to the engine-driven diffuser (fig. 2), and pumped environmental chambers coupled to a diffuser or ejector system for use during engine firing (fig. 3). Several techniques for vacuum generation exist. In addition to the conventional systems of mechanical pumps and steam boilers for steam ejectors, there are semi-portable liquid-propellant-driven steam generators.

GENERAL COMMENTS

Certain facts must be kept in mind when using the information in this report:

(a) Tabular listing, which is convenient to use, cannot provide sufficient detail to describe a facility completely. Only the most basic characteristics of the facility are included in the tabulation.

(b) Modification and expansion of facilities is a continuous effort.

(c) Many existing facilities can be varied to provide a wide range of environment, propellant combination, exhaust pressure level, starting and shutdown transients, types of data, recording capability, and accuracy.

The various columns of table I are described more fully as follows:

Operator; Owner: The operator is the division and/or corporation having jurisdiction of the facility. The owner is the corporation and/or government agency owning the facility.

Stand: The code or popular name by which the stand is known.

Location: The community or geographical area where the stand is located.

Type: The type of propulsion system, liquid and/or solid, that can be tested in the cell. (Several factors including exhaust-gas composition, scrubber capability, and available propellant plumbing and storage can affect the type of system tested.) Any predominant capability for a liquid-propellant combination that exists in the facility has been noted.

Rated thrust; Simulated altitude: The thrusts and altitudes shown are typical of a particular installation and are provided for geometrical considerations as well as facility capability. In some cases, mass-flow limitations as well as altitude at no engine flow (start conditions) are provided. Thrust and altitude were chosen as the major parameters of interest instead of mass flow, vacuum, and other factors such as maximum area ratio and blockage; cooling of combustion products; exhaust-product flow limitations (free hydrogen, solids, water vapor, etc.). Lastly, comments regarding safety considerations for facility, personnel, or the surrounding community are not included.

Environment: The manner in which the engine is coupled to the facility, either by encapsulation or by direct connection at the nozzle exit.

Attitude: The direction of firing or installation within the facility.

Vacuum generation: The equipment available to generate and/or maintain a vacuum condition.

Status: The operational or planning status as of the summer of 1963.

SUMMARY OF RESULTS

The modern high-performance upper stage and spacecraft rocket-engine systems require extensive testing. The proof of reliability in addition to an accurate determination of space performance of propulsion systems has placed a severe demand on test facilities capable of simulating altitude conditions. Therefore, a survey was made in order to provide a tabulation of altitude facilities available for rocket engine testing.

COMMENT

Because it is recognized that this tabulation may be incomplete, comments, corrections, and additions are solicited so that it may be revised.

Office of Advanced Research and Technology
National Aeronautics and Space Administration
Washington, D. C., March 12, 1964

TABLE I. - NATIONAL ALTITUDE ROCKET TEST FACILITIES, SUMMER 1963

Owner	Stand	Location	Type	Rated thrust, lb	Simulated altitude, ft	Engine environment	Attitude	Vacuum generation	Status
Operator, Arnold Engineering Development Center (AEDC)[a]									
Air Force	RAC T-1	Tullahoma, Tenn.	Liquid or solid	20,000 (Max., 490 lb_m/sec)	120,000 - Run	Capsuled	Horizontal	Pump	Operational
	RAC T-3			20,000	140,000 - Run				
	RAC T-4			20,000 (Max., 490 lb_m/sec)	120,000 - Run				
	RAC T-5B			3,000 (Max., 490 lb_m/sec)	150,000 - Run				
	RAC J-2			60,000	120,000 - Run				
	RAC J-2A			20,000	140,000 - Run 350,000 - Start				
	SRC J-3			100,000	100,000 - Run				
	VRC J-4		Liquid	500,000	100,000 - Run		Vertical		Operational 6/64
	SRC J-5		Solid	100,000	120,000 - Run		Vertical		Operational 6/64
Operator, Aerojet-General									
Air Force	C-2	Sacramento, Calif.	Liquid	100,000	70,000 - Run	Ambient	Horizontal	Diffuser	Operational
Air Force	C-3			100,000	160,000 - Start		Vertical	Pump and diffuser	
NASA	C-6			60,000	60,000 - Run		Vertical	Diffuser	
Air Force	E-5			200,000	160,000 - Start			Pump	
	G-6			100,000	70,000 - Run		Horizontal	Diffuser	
	G-7			5,000	60,000 - Run			Diffuser	
	H-3			100,000	60,000 - Run			Diffuser and plug	
NASA	H-3 (Apollo)			21,000	60,000 - Run			Diffuser	
	H-4			60,000	60,000 - Run			Diffuser	Operational 4/64
	H-5			Unknown	60,000 - Run			Ejector	Operational 3/64
	J-2			1,500,000	90,000 - Start		Vertical	Pump and steam ejector	Proposal for 1/65
	J-2			1,500,000	70,000 - Start 70,000 - Run		Horizontal	Diffuser and steam ejector	Proposal for 1/65
Aerojet-General		Azusa, Calif.		1.0 nominal lb_m/sec (800 max.)	60,000	Capsuled		Steam ejector	Operational
Air Force	P-1	Sacramento, Calif.	Solid	80,000 max.	220,000 - Start 40,000 to 80,000 - Run	Ambient		Pump and diffuser	
Navy	W-7			80,000 max.	220,000 - Start 40,000 to 80,000 - Run			Pump and diffuser	
AGC	W-10			8,000	220,000 - Start 40,000 to 80,000 - Run			Pump and diffuser	
Air Force	T-2			Variable	235,000 (Ignition conditions only)			Mechanical pump only	

Operator, Douglas Aircraft									
NASA	Stand A (6 engine)	Sacramento, Calif.	Liquid hydrogen and oxygen	15,000/engine	53,000 - Start 46,000 - Run	Ambient	Vertical	Steam ejector and diffuser	Operational
	Stand 2B			15,000/engine	53,000 - Start 46,000 - Run				Operational
	Beta Complex (A)			20,000	53,000 - Start 46,000 - Run				Operational fall-winter 1963
	Beta Complex (B)			20,000	53,000 - Start 46,000 - Run				Operational early 1964
Operator, Edwards Air Force Base									
Air Force	Test Area 1-14 (Cell A)	Edwards AFB	Liquid and solid	500 (2.5 lb_m/sec)	100,000	Capsuled	Horizontal	Steam ejector and diffuser	Operational (31 by 48 in. access door)
	Modification of Cell A	Edwards AFB	Liquid and solid	4,000	100,000	Capsuled	Horizontal	Steam ejector and diffuser	Operational
Operator, General/Dynamics									
Air Force - General Dynamics/ Astronautics	Centaur	Sycamore Canyon, Calif.	Liquid hydrogen and oxygen	15,000/engine	53,000 - Start 46,000 - Run	Ambient	Vertical	Ejector and diffuser	Operational
Operator, Pomona Division Ordnance Aerophysics Laboratory[b]									
Navy	4 ft diam.	Daingerfield, Texas	Liquid and solid	20,000	120,000	Capsuled	Horizontal	Pump and steam ejector	Operational
	10 ft diam.								Operational
	15 ft diam.								Operational[c]
Operator, Jet Propulsion Laboratory									
NASA	"D" Stand	Edwards AFB	Liquid and solid	800 50	85,000 122,000	Capsuled	Horizontal	Hyprox ejector and diffuser (For Hyprox ejector alone at 225,000 lb_m/hr of steam)	Operational (5 by 5 ft access door)
Operator, Lockheed Aircraft Corporation, California Div.									
Lockheed	C-1	Rye Canyon (near Burbank, Calif.)	Solid	5,000	150,000 - Start	Capsuled	Horizontal or vertical	Pump	Operational
	Propulsion Tunnel	Rye Canyon		10,000		Capsuled	Horizontal	Pump	Operational

[a]For additional information, see Test Facilities Handbook, Arnold Engineering Development Center.

[b]For additional information, see Ordnance Aerophysics Laboratory Facility Handbook, General Dynamics - Pomona, Daingerfield Division.

[c]High-temperature inlet air at 1600° F and 300 lb/sq in. added in summer of 1963; inlet air at 1800° F and 1000 lb/sq in. available early 1965.

TABLE I. - Concluded. NATIONAL ALTITUDE ROCKET TEST FACILITY INVENTORY, APRIL 1963

Owner	Stand	Location	Type	Rated thrust, lb	Simulated altitude, ft	Engine environment	Attitude	Vacuum generation	Status
Operator, Marquardt Corporation[d]									
Air Force	AF-MJL-VN Cell 8	Van Nuys, Calif.	Liquid and solid	20,000	90,000	Ambient		Pump, steam ejector, and diffuser	Operational
Air Force - NASA	Cell 6		Liquid	100	100,000		Vertical	Steam ejector and diffuser	
Marquardt - Air Force - NASA	Aerothermo Lab (ATL-4 Cells)		Liquid	100	100,000		Vertical		
Air Force	Rocket System Test Stand (20-in. diam. sphere)		Liquid and solid	230	160,000	Capsuled	Any direction		
Marquardt - NASA	North Test Area (Short Pulse)			25	400,000	Ambient	Horizontal	Diffusion and mechanical pump	
Marquardt - Air Force	Cell 2 (Minor Mod)			20,000	90,000			Pump and steam ejector or diffuser	
Marquardt - Air Force	Research Field Lab (RFL) 1 and 2	Saugus, Calif.		500	140,000			Steam ejector and diffuser	
Air Force	AF-MJL-O	Ogden, Utah		20,000	90,000			Pump, steam ejector, and diffuser	Idle
Operator, NASA Lewis Research Center									
NASA	PSL 1	Cleveland, Ohio	Liquid hydrogen and oxygen	15,000	100,000 - Start 75,000 - Run	Capsuled	Horizontal	Pump	Operational
	PSL 2		Liquid and solid	15,000	100,000 - Start 75,000 - Run		Horizontal and vertical		
	8 by 6 Foot Supersonic Wind Tunnel			2,000	35,000 - Run		Horizontal		
	10 by 10 Foot Supersonic Wind Tunnel			4,000	50,000 - Run		Horizontal		
	B-1	Plum Brook (near Sandusky, Ohio)							Proposed
	B-2		Liquid hydrogen and oxygen	45,000	150,000 - Run 10^{-5} (in. Hg) - Start			Diffusion pump, steam ejector, and diffuser	Operational 1/65
	B-3								Proposed
Operator, NASA Marshall Space Flight Center									
NASA	LHTS	Huntsville, Ala.	Liquid hydrogen and oxygen	15,000	46,000 - Run	Capsuled	Horizontal	Steam ejector and diffuser	Operational
	Vacuum chamber	Huntsville, Ala.	Liquid and solid	To 5,000	120,000 - Start	Capsuled	Horizontal or vertical	Mechanical pump	Operational

Operator, NASA Manned Spacecraft Center									
NASA	Undesignated	Clear Lake, Tex.	Liquid	2,000 to 5,000	46,000 - Run	Capsuled	Vertical	Steam ejector and diffuser	Operational (complete fall 1964)
Operator, Pratt & Whitney Aircraft Company, Florida Research & Development Div.									
NASA	E-1	West Palm Beach, Fla.	Liquid hydrogen and oxygen	15,000	53,000 - Start 46,000 - Run	Capsuled	Horizontal	Steam ejector and diffuser	Operational
	E-2			15,000	53,000 - Start 46,000 - Run				
	E-3			15,000	53,000 - Start 46,000 - Run				
	E-4			15,000	53,000 - Start 46,000 - Run				
	E-5 Dual Engine Stand			15,000/engine	53,000 - Start 46,000 - Run	Ambient	Vertical		
	E-6			15,000	53,000 - Start 46,000 - Run	Capsuled			
	E-7			15,000	53,000 - Start 46,000 - Run	Capsuled			
	B-3			15,000	53,000 - Start 46,000 - Run	Ambient	Horizontal		
Pratt & Whitney	Undesignated Area 10K Bay		Liquid hydrogen and fluorine	15,000	53,000 - Start 46,000 - Run	Ambient	Horizontal		
Operator, Rocketdyne Division of North American Aviation, Inc.									
NASA	VTS-3A	Santa Susanna, Calif.	Liquid hydrogen and oxygen	200,000	60,000 - Start 90,000 - Run	Capsuled	Horizontal	Ejector and diffuser	Operational
NASA	Delta-2A			200,000	60,000 - Start 90,000 - Run		Vertical	Ejector and diffuser	
Air Force	CTL-3 28B			100	110,000 - Start			Ejector	
	CTL-3 28C			25	130,000 - Run			Diffuser and ejector	
	CTL-39			300	100,000 - Run		All	Ejector	
	CTL-4 35A			50	150,000 - Start 110,000 - Run		Horizontal	Pump, diffuser, and ejector	
	CTL-4 35B			100	110,000 - Start 130,000 - Run		Horizontal	Ejector diffuser and ejector	
	CTL-4 37			300	150,000 - Start 80,000 - Run		All	Pump, diffuser, and ejector	
	CTL-4 38			100	120,000 - Start 100,000 - Run		All	Ejector Ejector	
Rocketdyne	Undesignated	Reno, Nev.		Similar to CTL-3 stands	100,000 - Run (nominal)		Vertical	Ejector	
Operator, Thiokol Chemical Corporation									
Navy	Undesignated	Elkton, Md.	Solid	20,000	100,000 - Start 70,000 - Run	Capsuled	Horizontal	Hyprox ejector and diffuser 250,000 lb/hr	Operational
	Stand 10B	Lake Denmark, Denville, N.J.	Liquid and solid	20,000	250,000 - Start 120,000 - Run	Capsuled or ambient	Vertical or horizontal	Hyprox ejector and diffuser 140,000 lb/hr	
	Stand 10B-1	Lake Denmark, Denville, N.J.	Liquid and solid	1,000 Max.	100,000	Capsuled or ambient	Vertical or horizontal	Ejector and diffuser	

[d]Several other cells have altitude capability with minor modification.

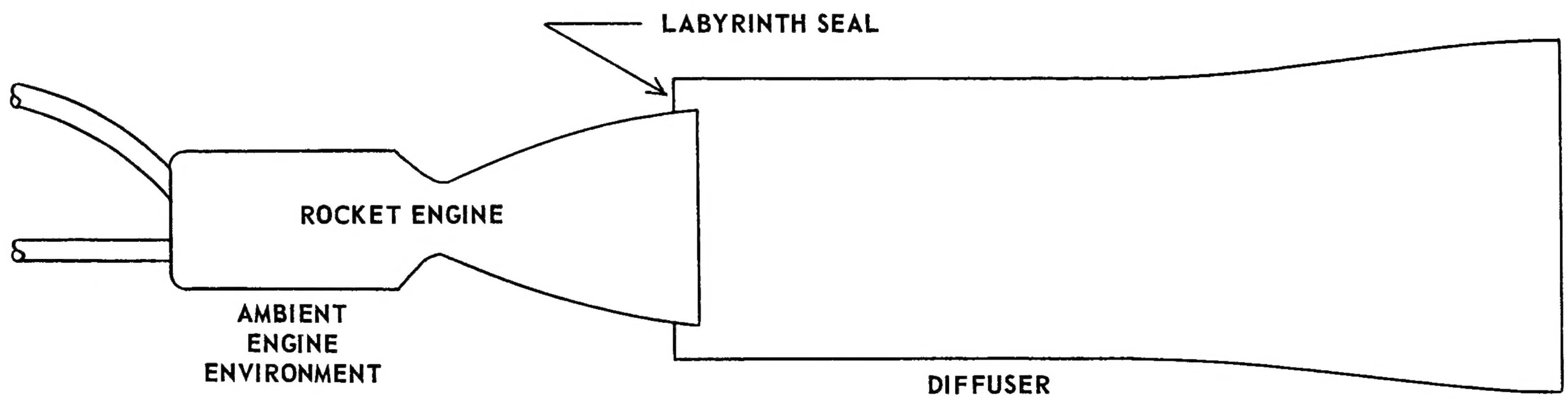

Figure 1. - Simple diffuser providing only altitude simulation at nozzle exit during firing.

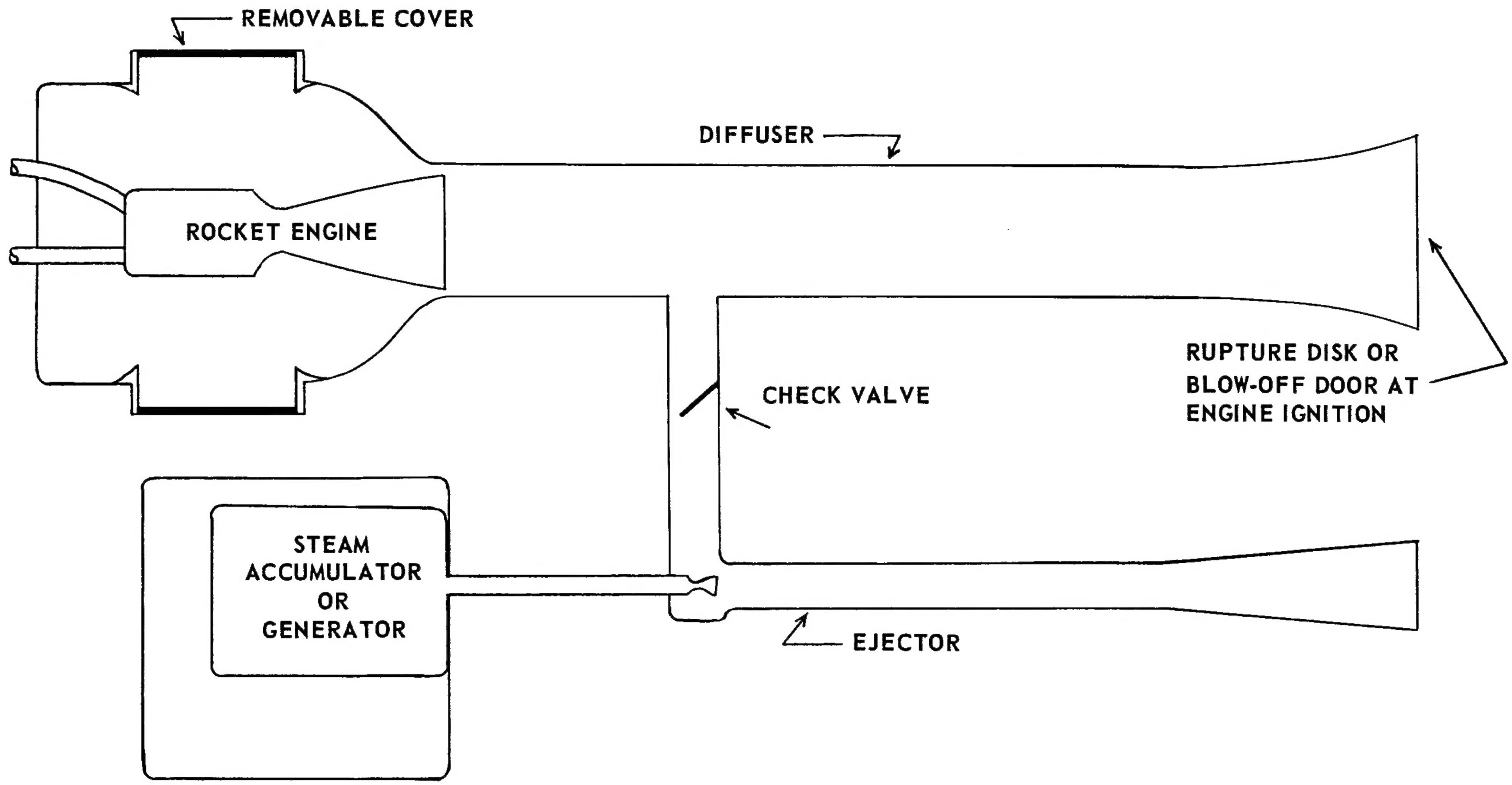

Figure 2. - Steam ejector and diffuser with an encapsulated engine providing altitude ignition with altitude environment before and during engine operation.

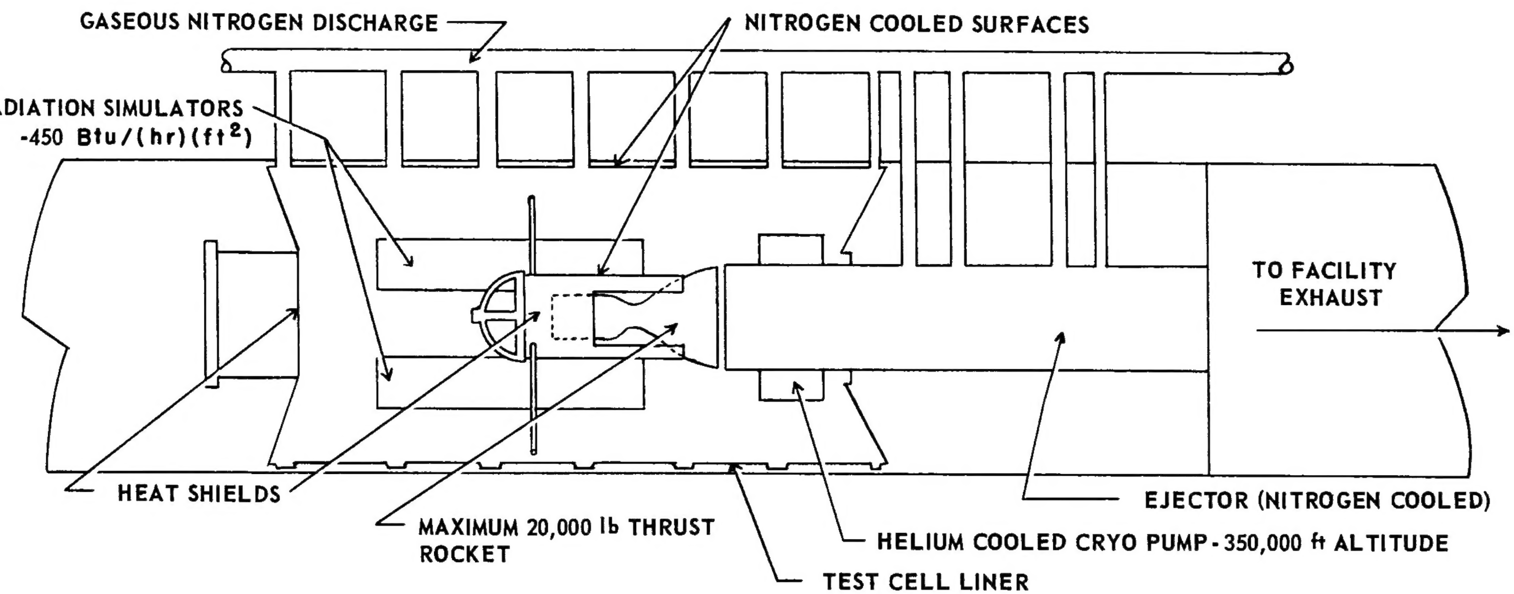

Figure 3. - Environmental chambers for long term space simulation with high altitude simulation at ignition and altitude simulation during engine runs. (AEDC-Cell J-2A)

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A tabular inventory of altitude test facilities available for testing rocket engines is provided. Included in the listing are ownership, contractual operator if applicable, code name of stand, geographic location, propulsion system type, nominal thrust level and operating altitude, engine operating environment, firing attitude, vacuum generation system, and status in summer of 1963.

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—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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